WHAT IS CLAIMED IS:

1.   An optical element consisting of a set of a plurality of three-dimensional cells, wherein:

5   a specific amplitude and a specific phase are defined in each individual cell,

and said individual cell has a specific optical property so that, when incident light is provided to the cell, emission light is obtained by changing an amplitude and a phase of

10   the incident light in accordance with the specific amplitude and the specific phase defined in the cell.

2.   The optical element as set forth in Claim 1, wherein each cell has an amplitude-modulating part provided with

15   transmittance corresponding to a specific amplitude.

3.   The optical element as set forth in Claim 1, wherein each cell has an amplitude-modulating part provided with reflectivity corresponding to a specific amplitude.

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4.   The optical element as set forth in Claim 1, wherein each cell has an amplitude-modulating part provided with an effective area corresponding to a specific amplitude.

25   5.   The optical element as set forth in Claim 1, wherein each cell has a phase-modulating part provided with a

refractive index corresponding to a specific phase.

6.   The optical element as set forth in Claim 1, wherein each cell has a phase-modulating part provided with an optical path length corresponding to a specific phase.

7.   The optical element as set forth in Claim 1, wherein each cell has a concave part formed by hollowing a part provided with an area corresponding to a specific amplitude by a depth corresponding to a specific phase.

8.   The optical element as set forth in Claim 7, wherein a surface where the concave part of each cell is formed serves as a reflecting surface, and incident light provided to the cell is reflected by the reflecting surface and thereby turns into emission light.

9.   The optical element as set forth in Claim 7, wherein each cell includes a main body layer having a concave part and a protective layer with which a surface where the concave part of the main body layer is formed is covered, and the main body layer and the protective layer are made of materials different from each other.

10.   The optical element as set forth in Claim 9, wherein the main body layer and the protective layer are made of

transparent materials different in a refractive index from each other, and incident light provided to the cell passes through the main body layer and the protective layer and thereby turns into emission light.

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11. The optical element as set forth in Claim 9, wherein a boundary between the main body layer and the protective layer forms a reflecting surface, and incident light provided to the cell is reflected by the reflecting surface and thereby

10 turns into emission light.

12. The optical element as set forth in Claim 1, wherein each cell has a convex part formed by protruding a part provided with an area corresponding to a specific amplitude

15 by a height corresponding to a specific phase.

13. The optical element as set forth in Claim 12, wherein a surface where the convex part of each cell is formed serves as a reflecting surface, and incident light provided to the

20 cell is reflected by the reflecting surface and thereby turns into emission light.

14. The optical element as set forth in Claim 12, wherein each cell includes a main body layer a convex part and a

25 protective layer with which a surface where the convex part of the main body layer is formed is covered, and the main

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body layer and the protective layer are made of materials different from each other.

15. The optical element as set forth in Claim 14, wherein the main body layer and the protective layer are made of transparent materials different in a refractive index from each other, and incident light provided to the cell passes through the main body layer and the protective layer and thereby turns into emission light.

16. The optical element as set forth in Claim 14, wherein a boundary between the main body layer and the protective layer forms a reflecting surface, and incident light provided to the cell is reflected by the reflecting surface and thereby turns into emission light.

17. The optical element as set forth in Claim 1, wherein each cell is arranged one-dimensionally.

18. The optical element as set forth in Claim 1, wherein each cell is arranged two-dimensionally.

19. The optical element as set forth in Claim 18, wherein a longitudinal pitch of each cell and a lateral pitch of each cell are arranged so as to be an equal pitch.

20.   The optical element as set forth in Claim 1, wherein a complex amplitude distribution of object light from an object image is recorded so that the object image is reconstructed when observed from a predetermined viewing point so as to be usable as a hologram.

21.   A method for manufacturing an optical element where a predetermined object image is recorded, the method comprising:

a cell defining step of defining a set of a plurality of three-dimensional virtual cells;

a representative-point defining step of defining a representative point for each virtual cell;

an object image defining step of defining an object image to be recorded;

an amplitude phase defining step of defining a specific amplitude and a specific phase in each virtual cell by calculating a complex amplitude at a position of each representative point of object light emitted from the object image; and

a physical cell forming step of replacing each virtual cell with a real physical cell and forming an optical element that consists of a set of three-dimensional physical cells;

wherein, at the physical cell forming step, when predetermined incident light is given to each physical cell, replacement is carried out by each physical cell having a

specific optical property so as to obtain emission light that has changed an amplitude and a phase of the incident light in accordance with a specific amplitude and a specific phase defined in the virtual cell corresponding to the physical

5   cell.

22.   The manufacturing method for the optical element as set forth in Claim 21, wherein, at the cell defining step, a cell set is defined by arranging block-like virtual cells

10   one-dimensionally.

23.   The manufacturing method for the optical element as set forth in Claim 21, wherein, at the cell defining step, a cell set is defined by arranging block-like virtual cells

15   two-dimensionally.

24.   The manufacturing method for the optical element as set forth in Claim 21, wherein, at the amplitude phase defining step, a plurality of point light sources are defined

20   on the object image, and object light of a spherical wave having a predetermined amplitude and a predetermined phase is regarded as being emitted from each point light source, and a totaled complex amplitude of the object light from the point light sources at a position of each

25   representative point is calculated at a predetermined standard time.

25. The manufacturing method for the optical element as set forth in Claim 24, wherein K point light sources that emit object light whose wavelength is λ are defined on the object image, and if an amplitude of object light emitted from a k-th point light source $O(k)$ ($k = 1$ to K) is represented as Ak, and a phase thereof is represented as θk, and a distance between a predetermined representative point P and the k-th point light source $O(k)$ is represented as rk, a totaled complex amplitude of the object light from the K point light sources at the predetermined representative point P is calculated as follows:

$$\Sigma_{(k=1,K)} (Ak/rk \cdot \cos(\theta k \pm 2\pi rk/\lambda)$$
$$+ iAk/rk \cdot \sin(\theta k \pm 2\pi rk/\lambda)).$$

26. The manufacturing method for the optical element as set forth in Claim 21, wherein, at the physical cell forming step, each virtual cell is replaced with a physical cell having a concave part formed by hollowing a part provided with an area corresponding to a specific amplitude by a depth corresponding to a specific phase.

27. The manufacturing method for the optical element as set forth in Claim 26, wherein:

a refractive index of a material filled in the concave part of the physical cell is represented as n1,

a refractive index of another material in contact with the material n1 is represented as n2,

a wavelength of object light is represented as λ,

a maximum depth dmax of the concave part is set to

5 be dmax $= \lambda / |n1 - n2|$,

a depth d corresponding to a specific phase θ is determined by the expression $d = \lambda \cdot \theta / 2(n1 - n2) \pi$ when n1 > n2, and is determined by the expression $d = dmax - \lambda \cdot \theta / 2(n2 - n1) \pi$ when n1 < n2, and

10 an object image is reconstructed by transmission light that has passed through the concave part.

28. The manufacturing method for the optical element as set forth in Claim 26, wherein:

15 a refractive index of a material filled in the concave part of the physical cell is represented as n, a wavelength of object light is represented as λ,

a maximum depth of the concave part is set to be dmax $= \lambda / 2n$,

20 a depth d corresponding to the specific phase θ is determined by the expression

$d = \lambda \cdot \theta / 4n \pi$, and

an object image is reconstructed by reflected light that has been reflected by the boundary of the concave

25 part.

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29. The manufacturing method for the optical element as set forth in Claim 26, wherein α kinds of a plurality of areas are defined as areas corresponding to a specific amplitude, β kinds of a plurality of depths are defined as depths corresponding to a specific phase so as to prepare $\alpha \times \beta$ kinds of physical cells in total, and each virtual cell is replaced with a physical cell closest in a necessary optical property among said physical cells.

30. The manufacturing method for the optical element as set forth in Claim 21, wherein, at the physical cell forming step, each virtual cell is replaced with a physical cell having a convex part formed by protruding a part provided with an area corresponding to a specific amplitude by a height corresponding to a specific phase.

31. The manufacturing method for the optical element as set forth in Claim 30, wherein:

a refractive index of a material that constitutes the convex part is represented as n1,

a refractive index of another material in contact with the material n1 is represented as n2,

a wavelength of object light is represented as λ,

a maximum height dmax of the convex part is set to be dmax = λ / |n1 - n2|,

a height d corresponding to a specific phase θ is

determined by the expression $d = \lambda \cdot \theta /2(n1 - n2) \pi$ when $n1 > n2$, and is determined by the expression $d = dmax - \lambda \cdot \theta /2(n2 - n1) \pi$ when $n1 < n2$, and

an object image is reconstructed by transmission light that has passed through the convex part.

32. The manufacturing method for the optical element as set forth in Claim 30, wherein:

a refractive index of a material that constitutes the convex part is represented as n, a wavelength of object light is represented as λ,

a maximum height dmax of the convex part is set to be $dmax = \lambda /2n$,

a height d corresponding to the specific phase θ is determined by the expression
$d = \lambda \cdot \theta /4n\pi$, and

an object image is reconstructed by reflected light that has been reflected by the boundary of the convex part.

33. The manufacturing method for the optical element as set forth in Claim 30, wherein α kinds of a plurality of areas are defined as areas corresponding to a specific amplitude, β kinds of a plurality of heights are defined as heights corresponding to a specific phase so as to prepare $\alpha \times \beta$ kinds of physical cells in total, and each virtual cell is replaced with a physical cell closest in a necessary

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optical property among said physical cells.

34. The manufacturing method for the optical element as set forth in Claim 21, further comprising a phase-correcting step of correcting the specific phase defined for each virtual cell in consideration of a direction of illumination light projected when reconstructed.

35. The manufacturing method for the optical element as set forth in Claim 21, further comprising a phase-correcting step of correcting the specific phase defined for each virtual cell in consideration of a position of a viewing point when reconstructed.

36. The manufacturing method for the optical element as set forth in Claim 21, wherein:

at the cell defining step, a cell set of virtual cells arranged on a two-dimensional matrix is defined by arranging the virtual cells horizontally and vertically,

at the amplitude phase defining step, a plurality of M point light source rows that are each extended in a horizontal direction and are mutually disposed in a vertical direction are defined on an object image, and M groups in total are defined by defining virtual cells that belong to a plurality of rows contiguous in the vertical direction in the two-dimensional matrix as one group,

the M point light source rows and the M groups are caused to correspond to each other in accordance with an arrangement order relative to the vertical direction, and

a totaled complex amplitude at a position of each representative point is calculated on a supposition that object light emitted from a point light source in an m-th point light source row (m = 1 to M) reaches only virtual cells that belongs to an m-th group.